One Idea and Three Concepts for Indoor-Outdoor Navigation

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Abstract: For pedestrian navigation when a precision of one step is required as for navigation of visually impaired people or if the envisaged mobile appplication needs to position POIs with a high precision, there is no real difference between indoor and outdoor navigation as an IMU-based localization system has to be used. IMU-based localization is not an absolute positioning system and proceeds by path integration so it must be associated to another kind of localization system such as GPS, WI-FI, RFID, IBR (Image-Based Recognition). Pedestrian navigation has to cope with the main difficulties encountered by visually impaired people, i.e. preplanning routes, recovery form unexpected detours and maintening heading. Path integration, 3D audio cues and structured environment are navigation aids used implicitly by visually impaired people and give them highly successful navigation. Our position is that a navigation system can be build starting from a conceptual definition of these three aids which are inter-related. Our prototype navigation system built above these three concepts, works indoor and outdoor when the environment is structured or has a regular layout. It's a complex system with many services and data exchanges between concurrent processes. For this reason, we have build it using XML and Web technologies, allowing easy personnalization of the level of navigation aid, and easy authoring of personnal audio cues and POIs on a specific itinerary.

Key-words: navigation, environmental queries, interactive audio, visually impaired people, mobile guidance.

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Une idée et trois concepts pour la navigation indoor-outdoor

Résumé : Pour la navigation pédestre de haute précision, il n'y a pas de différence entre navigation indoor et outdoor car seule une centrale d'inertie est utilisable pour la localisation. Cette centrale doit être couplée à une cartographie de haute-précision. La mémoire du chemin parcouru, l'audio 3D et un environnement strucuturé sont probablement les trois aides à la navigation utilisées implicitement par les personnes déficientes visuelles. Notre système de navigation est donc bâti sur ces trois concepts, en utilisant les technologies XML et Web qui facilitent la réalisation d'un système de cette complexité.

Mots-clés : navigation, interrogation de l'environnement, audio interactif, déficients visuels, guidage mobile

1 Augmented Reality Audio

As a general definition, Interactive Audio (IA) is a technology designed to allow specifically created audio, placed in a given application, to react to user input and changes in the application environment. For navigation systems, it is a way to provide user interactive information in a natural and non-intrusive way. In addition, by the mean of giving this information in real-time according to the user environment, an Augmented Reality Audio (ARA) system is created [2]. Interactive audio can be used to achieve different goals in such systems: enhancing the visual experience and immersion with 3D audio soundscapes, guiding the user with intuitive audio indications or adding dynamic and interactive content to POIs. The audio medium is very important in navigation systems as it does not distract the user from its visual focus.

1.1 XML Format for Interactive Audio

ARA applications use sound objects to create a soundscape. A sound object is a time structure of audio chunks whose duration is on the time scale of 100 ms to several seconds. These sound objects have heterogeneous and time-varying properties. In order to describe IA contents we created MAUDL (Mobile AUDio Language), an XML language inspired by iXMF that is well adapted to the design of dynamic soundtracks for navigation systems. MAUDL can be used as an authoring time interchange file format for interactive mobile applications or as a runtime file format that is actually loaded through the web and played directly in the mobile. MAUDL is a cue-oriented interactive audio system, audio services being requested using named events and the system's response to each event being determined by the audio artist.

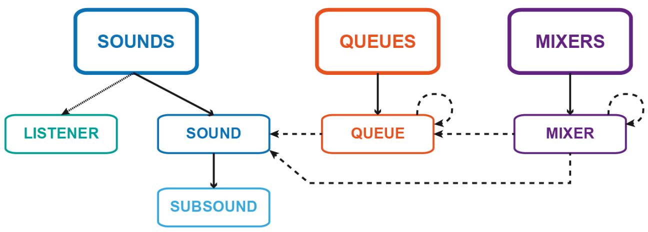

Figure 1: MAUDL: an interactive audio language.

The architecture of the MAUDL format is relatively simple and straightforward (fig. 1). The basic audio element is the sound, built from an audio file or voice synthesis. It may be composed by one or more subsounds for creating dynamic variations or we can just create a handy hierarchy of selectable audio elements, at the choice of the audio artist. As the sounds may be spatialized in 3D, you can specify the properties of the audio scene listener. Sounds can the be organized freely in a hierarchy of mixers, to create audio groups. Finally, instead of being played directly, sounds can be added to a queue that also acts at a content filter, based on priority, time and space settings. Queues elements are very important in a navigation context as they provide a simple way to give the user the best information at a given time by filtering automatically less-critical or outdated sounds. The format is modular and support cross-referencing elements between multiple documents. The event-based synchronization system supports both internal and external events in a way similar to SMIL, allowing complex soundtrack structure and random variations. In order to load MAUDL documents, we have developed a light and efficient sound manager API that works on mobile systems. This sound manager is used at the heart of our prototype of indoor navigation system. For more information, have a look at http://wam.inrialpes.fr/iaudio/.

1.2 Audio Integration in OSM POIs

The modularity of the MAUDL format allows it to be used directly in OpenstreetMap (OSM) POIs. This provides the possibility to add dynamic audio content to regular POIs, but also advanced cross-POIs audio interactions as the audio documents of multiples POIs may interact with each other through events. Creating rich multimedia POIs with images and audio is then made simple, as shown in the example below:

```
OSM Document
<relation id="22038" uid="178186">
   <member type="node" ref="GVAjardin"
      role="from"/>
   <member type="node" ref="GVAbastille"
      role="to"/>
   <member type="node"  ref="telepherique"
      role="to"/>
   <tag k="pano:resource" v="jardin.jpg"/>
   <tag k="pano:type" v="hemispherical"/>
   <tag k="pano:north" v="230"/>
   <tag k="audio:type" v="xml/maudl"/>
   <tag k="audio:resource" v="garden.xml"/>
   <tag k="content:type" v="html5"/>
   <tag k="content:resource" v="garden.html"/>
   <tag k="triggering" v="5.5"/>
   <tag k="visibility" v="4.5"/>
   <tag k="channel" v="culture"/>
</relation>

MAUDL Document
<maudl id="garden" >
  <sounds>
     <sound id="ambient" src="garden.mp3"
          play="poi.visible"/>
     <sound id="action" pick="random"
          play="poi.action">
        <subsound src="bird1.wav"/>
        <subsound src="bird2.wav"/>
        <subsound src="bird3.wav"/>
        </sound>
```

```
  </sounds>

</maudl>
```

1.3 3D Audio Pointer

In order to guide various categories of users, especially visually-impaired people, we use a 3D audio pointer build from several precomputed audio samples (fig. 2). This audio pointer give the user the azimuth using HRTF spatialized audio

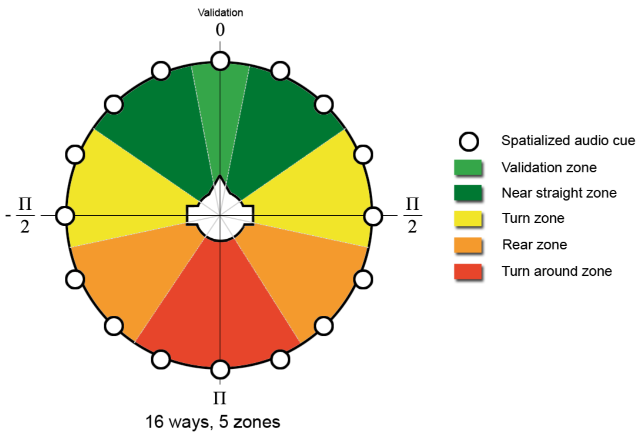

Figure 2: HRTF-based 3D Audio pointer.

cues, with additional hints taking the form of variation in the sound used: these are the 5 zones described above. A virtual 3D audio pointer provides an intuitive guide to the user, reducing the need for cognitive work. The pointer sound being simple, it also allows to superpose other kinds of audio contents such as voice while the pointer is active, to indicate distance for example. This kind of audio guide is suitable for different sorts of navigation systems, such as POIs browsers, self-guided audio tours or predefined route following applications.

2 Pedestrian Dead Reckoning

PDR denotes an inertial navigation system based on step information to estimate the position of the pedestrian. a PDR-based system allows people to be independant and can be used in both in indoor and outdoor environments. Such a system is based on a combination of inertial measurement unit (IMU), map-matching and advanced positioning algorithms. Different PDR systems exist, see [5] or [4] and can be attached on the waist, the thorax or a shoe. The proposed PDR is a low-cost and small-sized system using MEMS and CPU embedded in a smartphones. PDR algorithms hepl positioning the smartphone on the waist or on the thorax. The localization of the pedestrian is estimated using a tri-axial accelerometer, three gyros and magnetometers. Step detection and walking distance can be obtained by accelerometers. The azimuth can be computed by the data fusion of gyros and magnetometers [3].

2.1 Step Detection Algorithm

A PDR module is based on step detection. It is important to avoid false or missed detections because it can cause considerable errors in the estimation of the walking distance. Analysis of human walking has revealed some properties of the acceleration measured at the center of gravity of the person (located at the lower abdomen) or the thorax. Indeed, we note that at each step, the vertical acceleration makes a positive peak. We use a peak detection method as shown on fig 3..

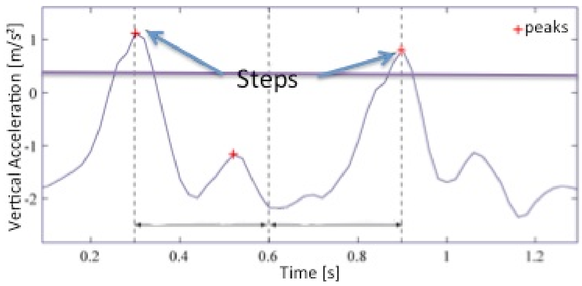

Figure 3: Step detection.

2.2 Physiological models of walking

2.2.1 Distance computation

The objective is to have the best walking distance accuracy. Different walking physiological models are studied to estimate step length. The calibration value is a parameter pre-learned during a calibration stage that can consist of a 30 meters walk. This calibration value is unique and reflects the walking characteristics of each pedestrian. The total walking distance is obtained by adding all step lengths calculated during the walk.

2.2.2 Azimuth computation

The azimuth is the angle between true north and direction of the walk. The computation of the azimuth with the gyroscopes can be calibrated to take into account the walking characterisitc of each person. Filtration of gyroscope data is based on step frequency and dominant direction. This allows recovery from unexpected detours, one of the main difficultie encoutered by visually impaired. Absolute azimuth positioning is done with the help of the compass, but magnetic disturbance have to be take into account specially indoor.

2.3 Map Matching

Map-matching is one of the key element to be used with a PDR module to obtain a localization. In the real world, most routes inside buildings happen along straight lines defined by corridors and walls, with dominant directions.

Outdoors, pedestrian navigation is structured by pedestrian crossing, sidewalks, pedestrian streets or tactile paving. Routes are represented as node-edge data in a digital map and we are using the OpenStreetMap format for both indoor and outdoor. Map matching is also used by the PDR to calibrate dynamically step length models or to correct azimuth errors during walk in a straight line. Figure 3 shows how is done map-matching when using a node-edge representation of the route.

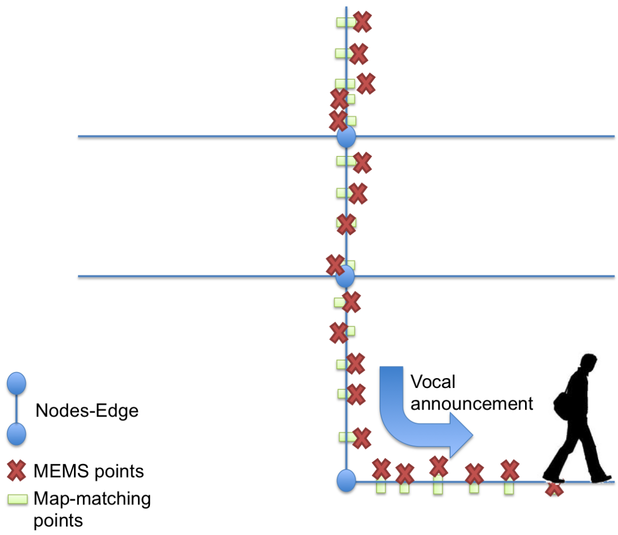

Figure 4: Map-matching.

2.4 Conclusion

A PDR-based localization is a low-cost solution to have a continuous localization for indoor-outdoor navigation. It works by using embedded sensors together with physiological models of walking. It gives navigation information like user position, azimuth and speed, which is then used by the 3D audio mdoule and the triggering module.

3 POI's Triggering and Environemental Queries

In augmented reality applications, Point Of Interest (POI) triggering is an important notion. According to the application context the triggering definition may change. What is triggered? When does a POI is triggered ? Where do we trigger a POI? Without use cases, it is hard to answer these questions. For augmented reality browsers such as Layar or Wikitude, triggering is specified by using a distance choosed by the user. All POIs contained in the defined field of view of the user will be displayed on a radar view and will overlay the main view. But as already said, we think that audio cues are important specially for a non-cognitive navigation. This use of audio POIs leads to new mode of trigerring than when using only visual information. Each POI describing an environment element (rooms, obstacles, stairs,etc.) is linked to an audio sound contributing to the soundscape. We use two POIs triggering modes for audio POIs. the first one, the « All Equal » mode is based on the front distance between the user and POIs and the second one, the « Autonomous POI mode » defines for each POI a specific distance or area in which the user has to come in.

3.1 Radar Mode and Environemental Queries

This concept is exclusively based on a specific distance between the user and all POIs in front of him. All environment elements found in this radar zone will build an immersive soundscape (figure 5) for the user allowing him to navigate in the building. Vocal announcements (turn left, go straight,etc.) are played differently because the triggering happens once the user enters in the POI triggering area. As shown on figure 5, a POI will be triggered if it is in the radar

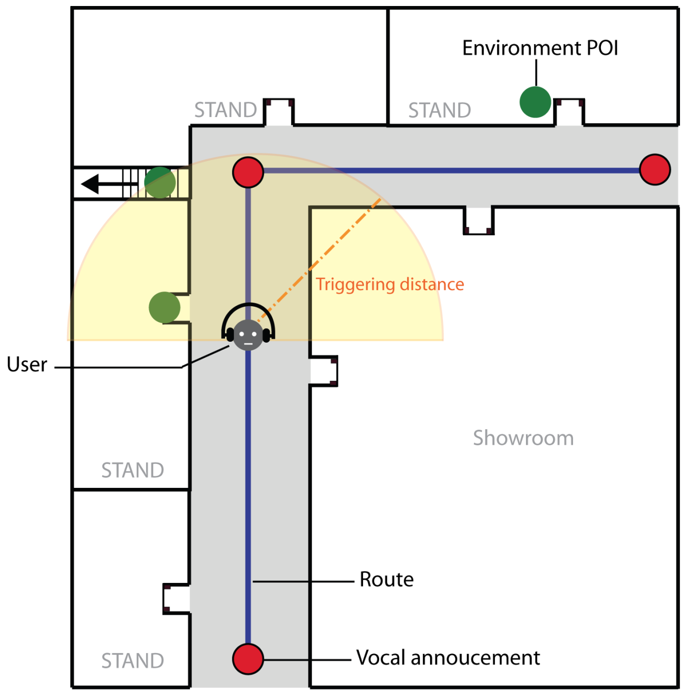

Figure 5: Radar Mode.

zone defined in front of the user. This radar-type process allows querying the environment according to several levels thanks to different radar zones (figure 6). First level triggers the nearest point of interests, second level gives information on all the ways that the user can take and finally, the last and third level give information on relations in the sense OpenStreetmap semantic. During navigation, it is important to know that surrounds you at different distances. Anytime in our system, you can stop walking and retrieve information about the environment, information which strutured by using three zones, short, medium and long distance zones.

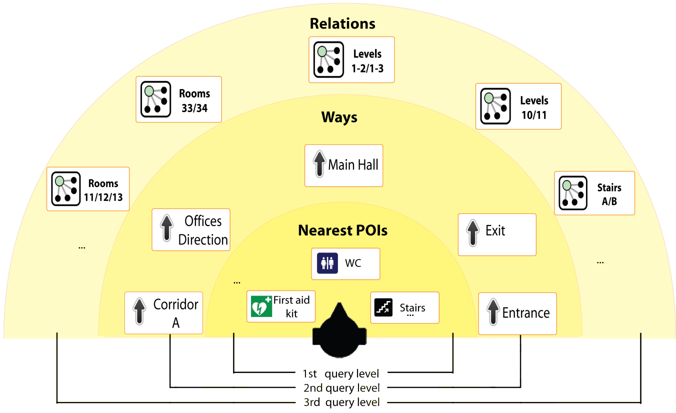

Figure 6: Radar and Triggering Distance.

3.2 Autonomous POI Mode

In the « all equal » triggering mode, it was not possible to trigger a distant POI without triggering nearest POIs. In this new mode, the triggering is not only be defined using the user position but some responsability is given to the POIs themselves. As a consequence each POI embeds its own triggering distance (figure 7) and the user no longer manages a radar zone like in the « All equal » process. The main interest of this solution is the priorities management for the benefit of the user. To illustrate this point, a dangerous obstacle will have a triggering distance higher than any point of information.

4 Routing Simulator

4.1 Multimedia tools for processing workflow

The goal of our routing simulator is the preplanning of routes. We use the OpenStreetmap format both for indoor and outdoor geographical data representation. But maximum zoom of OSM tiles visualizers is 18 for computational reasons, and that is not enough for indoor preplanning of routes. To suit our needs, we have developed a visualizer based on SVG, enabling infinite zoom and to address pedestrian navigation simulation, we use the SMIL module (a declarative format time structured objects) embedded in SVG. Our next version of the simulator will use HTML5, CSS3 and SMIL Timing/Timesheets [1] and will me more powerful.

4.2 Pedestrian Navigation Simulator

By overlaying SVG floor maps and routing indications extracted from a GPX file and transformed with XSLT in SVG fragments, we have created a pedestrian navigation simulator web application.To cope with levels in a building, we organize route's parts in a slideshow presenting as many slides as floors in the route. Animation of a route's part is synchronized on the end of the previous.

The XSLT transformation of the GPX route injects SVG audio fragments (vocal announcement), synchronized on waypoints. This is a powerful way of

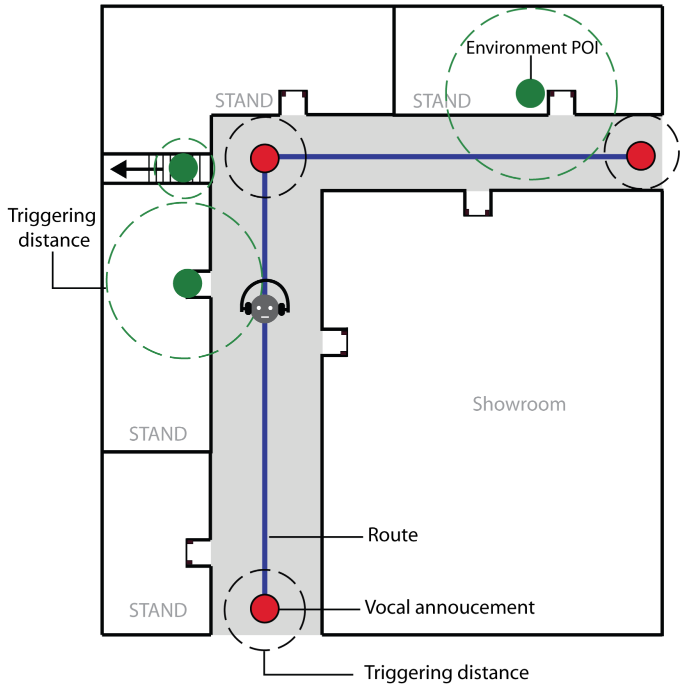

Figure 7: Autonomous POI Mode.

choreographing route preparation.

```
SVG Routing Fragment
  <g id="slideshow" smil:timeAction="intrinsic"
      smil:timeContainer="seq" smil="active"
      transform="matrix(1, 0, 0, 1, 0, 0)">
    <!-- first slide -->
    <g id="floor1" smil:dur="30s">
      <g id="structure1">
         <!-- first floor-->
      </g>
      <g id="route1"> <!-- route  --> </g>
      <g>
         <use xlink:href="#user">
           <audio xlink:href="sounds/5m3h.ogg"
               volume="0.7" type="audio/vorbis"
             begin="anim1.beginEvent" dur="5s"/>
                <!-- in 5meters turn a 3hours -->
           <audio xlink:href="sounds/d20.ogg"
                volume="0.7" type="audio/vorbis"
         begin="anim1.beginEvent+8s" dur="3s"/>
           <!-- in 20meters go straight on -->

           <animateMotion begin="0s" dur="30s"
                fill="freeze" id="anim1">
```

```
              <mpath xlink:href="#way1"/>
          </animateMotion>
       </use>
     </g>
     <!-- second slide -->
      <g id="floor2" smil:dur="30s">  </g>
     <!-- other floors description -->
  </g>
```

This simulator can also be used as remote controlled assistive navigation system, for example a call center for visually impaired people. Users device sends its position, while a family member, a friend or an assistant visualizes the itinerary and the environment on the map to help him.

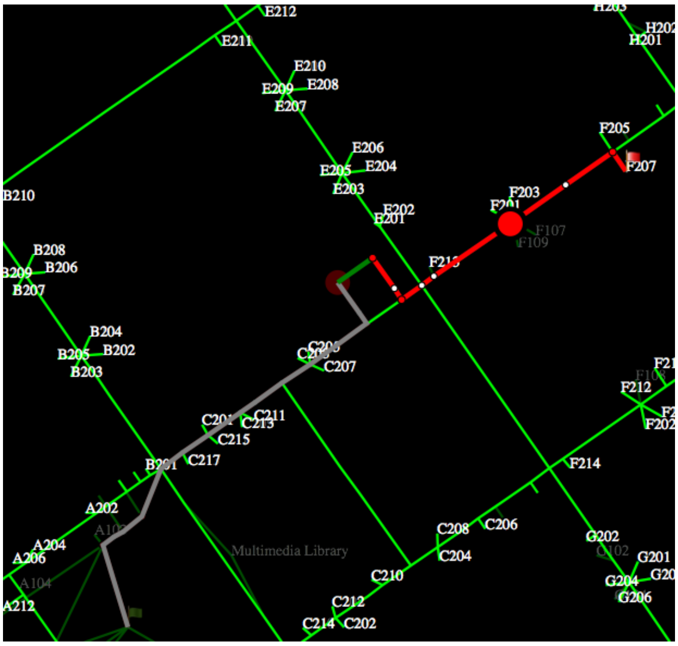

Figure 8: Preplanning routes.

5 Conclusion

To conclude, we think that for pedestrian navigation when a precision of one step is required as for navigation of visually impaired people or if the envisaged mobile appplication needs to position POIs with a high precision, there is no real difference between indoor and outdoor navigation as an IMU-based localization system is the only solution. Such a system has to cope with the main difficulties encountered by visually impaired people, i.e. preplanning routes, recovery form unexpected detours and maintening heading. Even if some progress has be done, we are still far to provide a good help to lower these difficulties. Pedestrian navigation is and will remain for several years a big challenge.

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